Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2022/2023

COURSE NAME	:	POWER SYSTEM ANALYSIS AND PROTECTION
COURSE CODE	:	BEF 43303
PROGRAMME CODE	:	BEV
EXAMINATION DATE	:	FEBRUARY 2023
DURATION	:	3 HOURS
INSTRUCTION	:	1. ANSWER **ALL** QUESTIONS 2. THIS FINAL EXAMINATION IS CONDUCTED VIA **CLOSE BOOK** 3. STUDENTS ARE **PROHIBITED** TO CONSULT THEIR OWN MATERIAL OR ANY EXTERNAL RESOURCES DURING THE EXAMINATION CONDUTED VIA **CLOSED BOOK**

THIS QUESTION PAPER CONSISTS OF **TEN (10)** PAGES

Q1 (a) Define the meaning of swing bus in power flow analysis.

(2 marks)

(b) The single line diagram of a three-generator power system is shown in **Figure Q1(b)**. Redraw the diagram to show all impedances in per-unit values as referred to a 7000 kVA base.

(7 marks)

(c) A three-phase 500 kV, 50 Hz transmission line between power stations A and B is 85 km long and is assumed lossless. The line inductance is 0.8 mH/km per phase, and its capacitance is 0.012 μF/km per phase.

(i) Determine the line phase constant, β and the surge impedance, Z_c.

(2 marks)

(ii) The rated load at receiving end is 1400 MW, 0.85 power factor lagging and operating at 500 kV. Analyze the sending end voltage, V_s and current, I_s.

(7 marks)

(d) A simple power system network is shown in **Figure Q1(d)**. The generators at buses 1 and 2 are represented by their equivalent current sources with their reactances in per-unit on a 100 MVA base. The lines are represented as series reactances in per-unit on a 100 MVA base. The shunt reactances are neglected. The loads at buses 3 and 4 are expressed in MW and MVAr. Assuming a voltage magnitude of 1.0 per-unit at buses 3 and 4, construct the bus admittance matrix representing the system.

(7 marks)

Q2 (a) Name the fault in which positive, negative, and zero sequence component currents are equal.

(1 mark)

(b) A single-line diagram of a power system is shown in **Figure Q2(b)**, where all the zero-sequence, positive-sequence, and negative-sequence reactances are given in per-unit. The transmission line reactance is given in ohms. The neutrals of the generator and Δ–Y transformers are solidly grounded. The motor neutral is grounded through a reactance $X_n = 0.05$ per-unit on the motor base.

(i) Convert the zero, positive, and negative sequence impedance of the transmission line to per-unit.

(2 marks)

(ii) Draw the per-unit zero, positive, and negative sequence networks on a 100 MVA, 13.8 kV base in the generator zone and assume the pre-fault voltage at both generator and motor is $1.05\angle 0°$ per-unit.

(3 marks)

(iii) Arrange the sequence networks to their Thevenin equivalents, as viewed from Bus 2.

(3 marks)

(iv) Analyze the line fault current (I_F) in per-unit and kA for a single line-to-ground short circuit at phase A at Bus 2.

(4 marks)

(c) Explain the importance of the power angle curve in power system stability.

(2 marks)

(d) **Figure Q2(d)** depicts a single line diagram of a three-phase, 50 Hz synchronous generator connected to an infinite bus through a transformer and parallel transmission lines. All reactances are given in per-unit on a 100 MVA base.

(i) Prepare the equivalent circuit to show all the reactances between the generator and infinite bus.

(2 marks)

(ii) Determine the current flowing into the infinite bus if the infinite bus receives 1.0 per-unit real power at 0.90 power factor lagging.

(2 marks)

(iii) Analyze the generator's internal voltage, E' for the operating conditions in **Q2(d)(i)**.

(4 marks)

(iv) Formulate the equation for the electrical power delivered by the generator versus its power angle, δ.

(2 marks)

Q3 (a) Consider a 4-busbar power system network as shown in **Figure Q3(a)**. It consists of 4 generators, 4 transformers, 5 transmission lines, and a fault at Bus 4. The whole network is divided into different zones of protection, provided with their respective circuit breakers.

(i) Differentiate the protective zones of distance relays by using an appropriate figure. Please use pen of different colors or line types to highlight the difference.

(7 marks)

(ii) Assign appropriate names to the zones of protection.

(2 marks)

(b) **Figure Q3(b)** shows a radial distribution system with 4 bus bars, 3 loads, and 3 overcurrent relays of IEC Standard Inverse characteristic. The system is protected through primary and backup overcurrent protection, with the fastest time multiplier setting (TMS) for each relay is being 0.025, and the coordination time interval (CTI) between the primary and the backup protection should be set at 0.3s. **Table Q3(b)** shows the maximum load current, the minimum fault current, and the maximum fault current of each feeder in the system, respectively.

(i) Highlight the plug setting multiplier (PSM) settings for primary and back-up protection.

(3 marks)

(ii) Determine the minimum pickup current for each relay.

(3 marks)

(iii) Calculate the maximum pickup current for each relay.

(3 marks)

(iv) Analyze the pickup current for each relay.

(3 marks)

(v) Justify the values of each relay pickup current, calculated at **Q3(b)(iv)** with respect to **Table Q3(b)** to be true.

(4 marks)

Q4 (a) **Figure Q4(a)(i)** shows a single line diagram of a radial system distribution grid. Assume that the coordination time interval for the relay is 0.3 seconds and the voltage is 11 kV (LL) at all buses during normal operation. Also, assume that the breaker operating time is 5 cycles, and the CT ratio is 200:5. Determine the current tap settings (TSs) and time-dial settings (TDSs) to protect the system from fault using CO-8 overcurrent relay. The characteristic of the CO-8 relay is shown in **Figure Q4(a)(ii)**.

(14 marks)

(b) With the aid of a single-line diagram, recommend the suitable configuration of differential relays for the following applications.

(i) Busbar protection.

(3 marks)

(ii) Transformer protection.

(3 marks)

(c) Consider a transformer differential protection as shown in **Figure 4(c)**. Determine the primary current I_P and secondary current I_S for the 30 MVA transformers at the CTs' output. Ignore the impedance of the cables and consider the impedance of the transformers as 6%, and a 3-phase fault occurring on the 33 kV side of the transformer outside its zone of protection.

(5 marks)

– END OF QUESTIONS –

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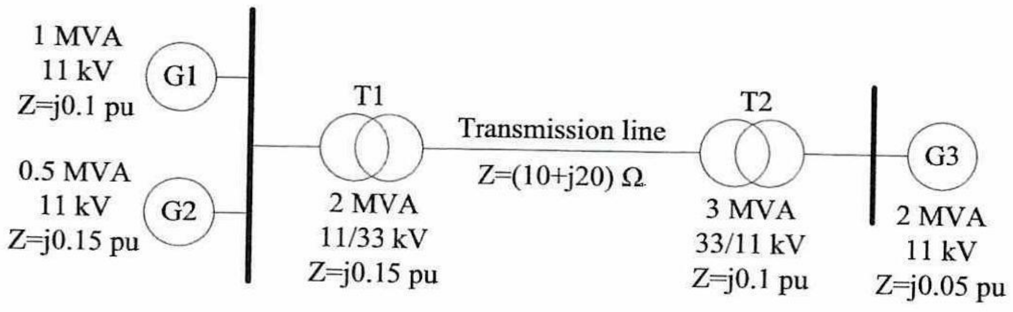

Figure Q1(b)

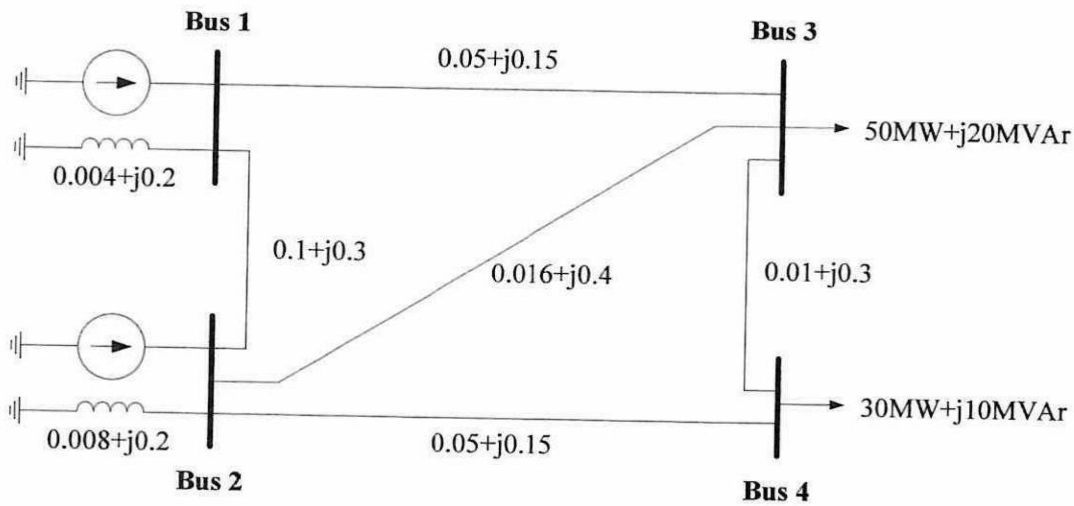

Figure Q1(d)

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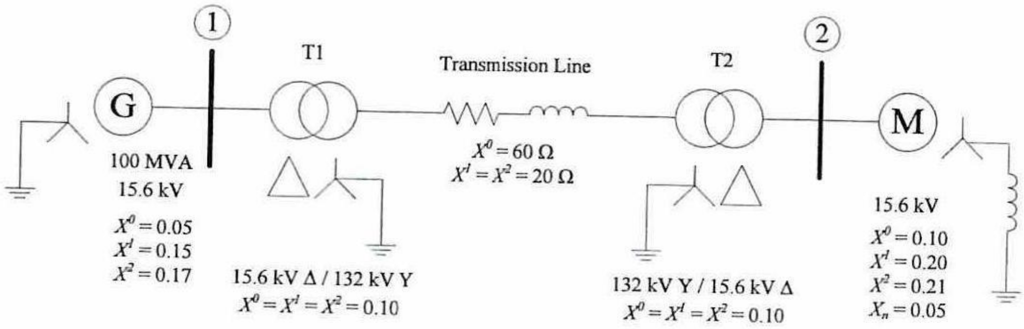

Figure Q2(b)

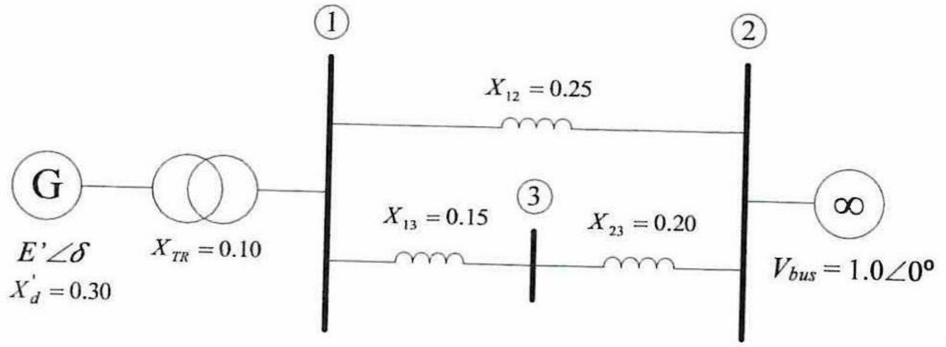

Figure Q2(d)

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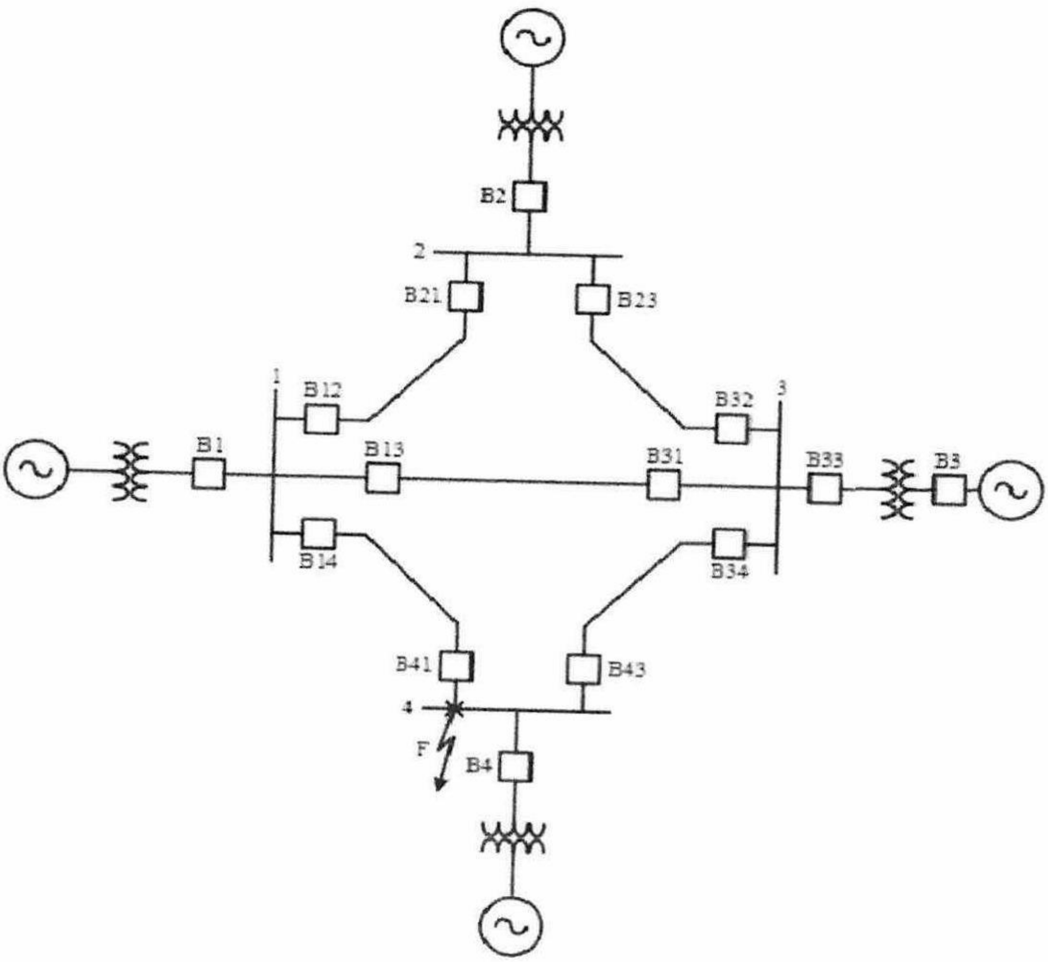

Figure Q3(a)

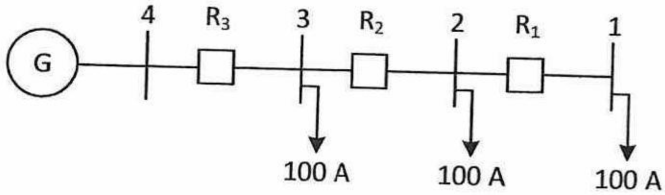

Figure Q3(b)

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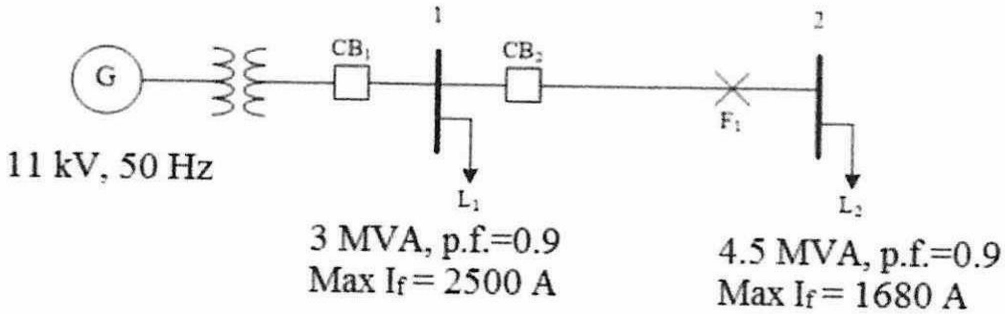

Figure Q4(a)(i)

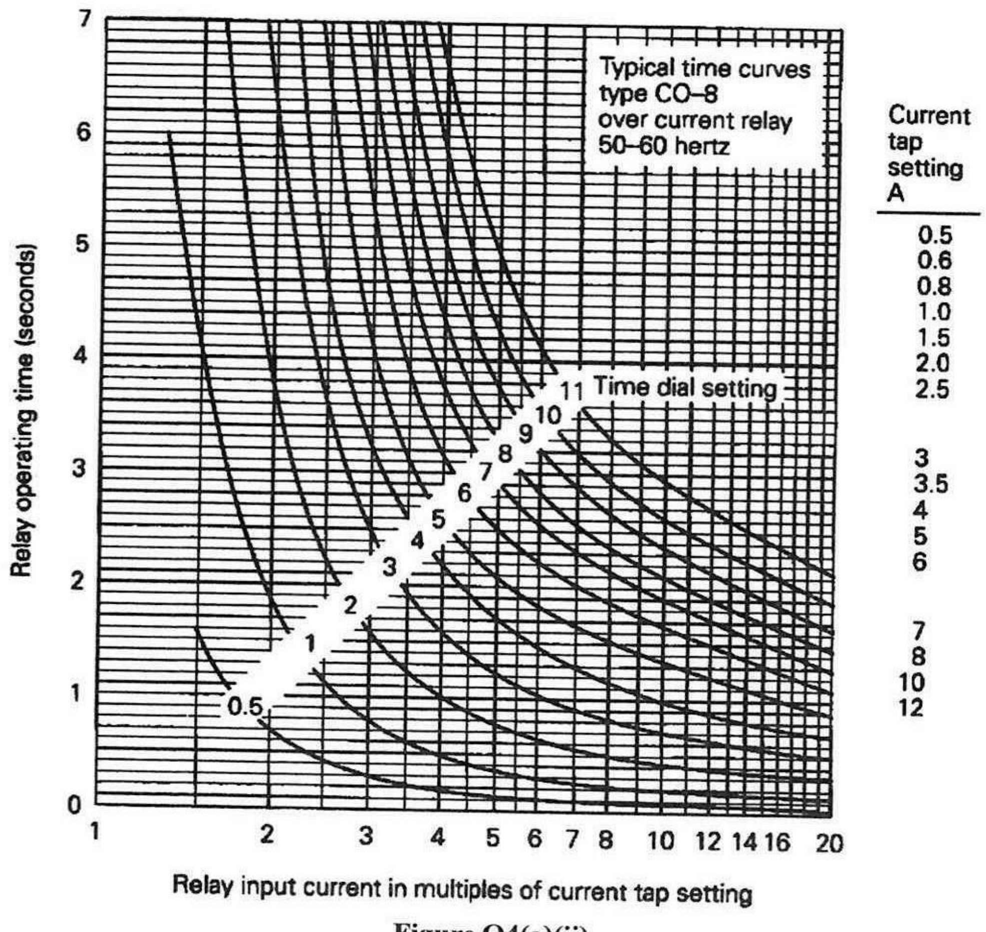

Figure Q4(a)(ii)

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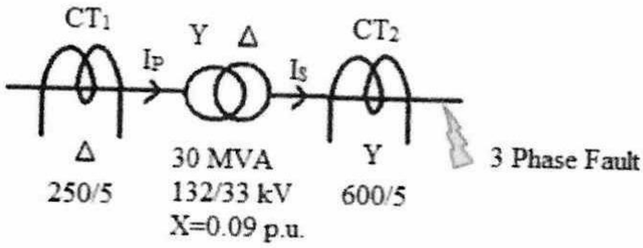

Figure Q4(c)

Table Q3(b)

Relay	Maximum Feeder Load Current (A)	Minimum Fault Current (A)	Maximum Fault Current (A)
R_1	100	300	500
R_2	200	600	1400
R_3	300	1200	2200